Testing Internet of Things:
An Enhanced Combinatorial Testing and Graph-based Technique

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The Problem, Need and Industrial Relevance

• Testing IoT systems is challenging
  – IoT is a complicated system with heterogeneous devices and different software
    ‣ Software behavior can be affected by the heterogeneous devices
  – IoT is highly scalable
    ‣ Very easy to have more than 100 different devices in IoT
  – Communication channels between different devices can fail
  – No evaluation metrics for IoT testing
    ‣ Industry still uses the traditional software metrics for IoT testing
**Project Goals and Objectives**

- Provide a guidance on which set of connections and in what order you should test for a particular IoT system
  - Systematically and effectively test the entire IoT system

  ![Diagram](image)

  Where should I start?

- Measure the test coverage based on the tested connection of the system
  - Identify the connections that still require testing

  ![Diagram](image)

  Did I miss anything?
The Proposed Approach and Its Novelty

Unlike other IoT testing approaches that only focus on the concrete testing level, the proposed technique

- provides an effective and efficient guidance at connection level
- integrates with concrete testing techniques (e.g., combinatorial testing, symbolic execution, security testing, etc.)

Step 1: Model an IoT system by a directed graph

Step 2: Identify connections of length \( n \)

Step 3: Prioritize the identified connections

A connection with the highest priority

Step 4: Test generation for the prioritized connection using CT

Step 5: Update information (e.g., code coverage)

Many iterations
Mode Construction

Network Devices

Decision Trigger

Aggregators

eUtilities
Identify Testable Connections

- Identified testable connections (length = 3)
  - [C1, V1, N1, E1]
  - [C2, V1, N1, E1]
  - [S2, D7, N1, E1]
  - [S3, D7, N1, E1]
  - [E1, N1, A2, E5]
  - [E1, N1, N2, E2]
  - [E2, N2, N1, E1]

A connection that only produces intermediate data is barely testable because of the difficulty in verifying the data.

They will not be identified as testing candidates.
Some connections should be first

- Connections that contain more eUtilities
  - Since devices purchased from other vendors (e.g., switch, router) have already been tested, our testing should focus on devices with customized software installed
- Connections that contain more devices
  - Test these connections first can quickly cover a large number of devices
- Connections that have lower code coverage
  - Connections with lower code coverage are more likely to fail compared to those with higher code coverage

Priority factors can be included and more prioritization factors can be included.

A Connection $c$

$$\text{Priority}(c) = \sigma \times \left( \alpha \times I_E(c) + \beta \times I_D(c) + \gamma \times I_C(c) \right)$$

Weights of Factors

- eUtility Factor
- Device Number Factor
- Code Coverage Factor

Priority Factors
The identified connection with top priority will be tested using effective and efficient testing technique (such as the enhanced combinatorial testing technique, symbolic execution, etc.)
Model Construction & Visualization
Connection Identification

Length 3 Testable Connection = ['E2', 'N2', 'N1', 'E1']

Length 3 Testable Connection = ['E3', 'A2', 'N1', 'E1']

Length 3 Testable Connection = ['E3', 'A2', 'N1', 'E1']

Length 3 Testable Connection = ['E4', 'A2', 'N1', 'E1']
## Current Progress, Milestones, and Deliverables

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Questions